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Rain and the city: Pathways to mainstreaming rainwater harvesting in Berlin

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Abstract

Studies of rainwater harvesting regularly highlight the rich diversity of technologies used to collect, treat and reuse rainwater in cities, but rarely devote attention to the equally diverse visions that drive rainwater harvesting projects. To rectify this omission this paper presents research from a city – Berlin – which has a long pedigree of rainwater harvesting that has given rise, over the past 30 years, to an astonishingly varied range of schemes. From a database of over 250 rainwater harvesting projects we select, analyse and compare three case studies which encapsulate three distinct project types prevalent in the city: public, grassroots and commercial. The paper demonstrates the nature of diversity between the three and illustrates how diverse logics of rainwater harvesting co-exist within one city. More significantly, it shows how each scheme reflects a particular imaginary of why urban rainwater should be harvested, how and for whom, and how these imaginaries have emerged out of particular institutional and infrastructural contexts in the course of Berlin's post-reunification development. These empirical findings are interpreted using STS concepts relating to sociotechnical imaginaries, urban infrastructures in transition and institutional obduracy and change.

Keywords: Rainwater harvesting, sociotechnical imaginaries, urban infrastructure, Berlin

1 Introduction

The literature on sustainable urban development in general, and on sustainable urban rainwater management in particular, frequently emphasizes the importance of moving away from conventional storm- and rainwater management using large-scale, piped infrastructures towards more decentralized, nature-based solutions (e.g. Cettner et al., 2014; Brown et al., 2013; Ward et al., 2012;

Sharma et al., 2010; Brown and Farelly, 2009). These alternative solutions for harvesting rainwater – involving such technologies as green roofs, artificial wetlands, permeable pavements and infiltration trenches – are deemed to be better suited to manage rainwater in densely-populated cities, even more so in the wake of climate change. They are accredited with providing multiple benefits such as groundwater replenishment, flood control, aesthetic and leisure value (Cettner et al., 2014; Sharma et al., 2010), being more readily adapted to local conditions (Petrucci et al., 2013; Sharma et al., 2010) and reducing water use (Ward et al., 2012; Domènech et al., 2015).

The arguments stacked up in favour of rainwater harvesting are, however, not translating into a serious challenge to conventional centralized systems. Although many cities of the global South continue to rely on local rainwater collection and use (Furlong, 2014; Meehan, 2014), in the global North the transition of urban rainwater harvesting (URWH) from niche to mainstream is not happening (Ward et al., 2012). Only a handful of developed cities, such as Melbourne (Brown et al., 2013), have reconfigured existing rainwater infrastructures around URWH principles. Elsewhere, there is generally "a consistent failure to go beyond *ad hoc* demonstration projects" (Brown and Farrelly, 2009: 839). This implementation gap is widely attributed in the literature to non-technical factors, primarily to unfavourable institutional contexts and obdurate socio-technical regimes. Recent social science contributions at the interface of urban water management and socio-technical transitions have significantly broadened our understanding of the multiple factors involved in mainstreaming URWH, drawing attention to the role of visions, leadership, path dependencies, regulatory frameworks, risks, expertise and bridging organisations (Brown and Farrelly, 2009; Brown et al., 2013; de Haan et al., 2015). Although this research is often founded on city-based case studies, it rarely explores the nature of the 'urban' in URWH policies and projects. The cities studied are treated merely as sites of innovation (or counter-innovation), rather than constituent factors behind URWH trajectories. This is rather odd, given that scholars of human geography and urban studies have over recent years made a concerted effort to rectify the spatial blindness of early transitions research (Hodson and Marvin, 2009; 2010; Bulkeley et al., 2011a; 2011b; Coenen et al., 2012; Wolfram and Frantzeskaki, 2016). Essentially, this body of work makes the case that sociotechnical transitions in cities – such as towards URWH – cannot be understood fully without appreciating how they get caught up in, and infused by, urban structures and processes, politics and practices.

The following paper draws on this relational understanding of urban infrastructures to analyse the complex and dynamic relationship between rainwater management and the city. As a case study for this analysis it uses the city of Berlin. Berlin lends itself well to a study of the urban trajectories of rainwater harvesting for two principal reasons. First, it was originally a pioneer of urban sustainable rainwater systems in industrialized cities in the late 1980s and has since spawned abundant and varied pilot projects. This permits a long-term analysis of URWH in a single city covering a span of 30 years. Second, Berlin has today lost this pioneering status to other cities, notably in Australia, the United States and Brazil (Brown et al., 2013; Meehan and Moore, 2014). Despite the large numbers of URWH schemes in operation across the city, the transition from niche to mainstream has proven more elaborate and elusive than the pioneers had originally hoped.

This raises questions about the relationship between rainwater technologies, sociotechnical transitions and urban contexts. Four guide the research on this paper: 1) To what ends and by what means has URWH been promoted in Berlin since the 1980s? 2) What kinds of URWH projects emerged during this period? 3) How can these policies and projects be understood in terms of interactions between urban development and rainwater management? 4) How can the findings advance

knowledge on the role of the 'urban' in sociotechnical transitions? The analytical focus of the paper is, therefore, on the shifting urban contexts of policy mechanisms and project dissemination. Informal norms and practices of rainwater use – although highly relevant to URWH in general – are not pertinent to this study of policy adaptation within a universalized and centralized urban rainwater regime.

The following section (2) positions the paper within scholarly debates on urban rainwater harvesting, sociotechnical transitions and reconfiguring urban infrastructures, highlighting its contribution to the interfaces between these fields and to human geography. The subsequent sections address the four core questions in turn. Section 3 identifies and analyses the policies, plans and programmes designed to promote URWH in Berlin, looking at multiple types of instruments (regulatory, planning, financial, organizational), policy sectors (water management, environmental protection, urban development) and geographical scales (EU, federal, state, borough) and setting them in the context of the city's shifting political economy. Section 4 presents a database of over 250 URWH projects in Berlin, analysing these in terms of their timing, geographical location, technical design, size and purpose (residential, public or commercial). Section 5 then interprets the empirical findings through the lens of rainwater-city interactions, drawing on analytical categories developed in section 2. The concluding section 6 summarizes the main arguments and discusses their relevance for research at the interface between urban geography and sociotechnical transitions.

2 Transitions towards urban rainwater harvesting

Local, small-scale rainwater harvesting was the norm across the world prior to the dissemination of large technical systems designed to remove rainwater from conurbations via neworks of sewers. Whilst rainwater harvesting has never been displaced in many communities of the global South (Furlong, 2014; Meehan, 2014), it was largely discarded in industrialized cities from the mid-nineteenth century onwards (Melosi, 2000). Today, however, the multiple benefits of URWH, summarized above, are encouraging urban planners to promote and even prioritize URWH technologies over incumbent systems. Much has been written about the gap between the rhetoric and the realities of mainstreaming rainwater harvesting that does not need to be repeated here (see Stahre, 2002; Rauch et al., 2005; Roy et al., 2008; Brown and Farrelly, 2009; Winz et al., 2011; Karvonen, 2011; Barbosa et al., 2012; Cettner et al., 2012; 2014). This section targets not this general debate on URWH but, rather, two strands of the literature which set out to interpret URWH in terms of transitions research (section 2.1) and sociotechnical transitions in terms of the 'urban' (section 2.2).

2.1 Understanding transitions to urban water management

Much of the work by social scientists on the implementation problems of URWH has been powerfully informed by institutionalist and/or agency-based frameworks. It is only very recently that some of these scholars have begun to explore how the literature on sociotechnical transitions (with its related fields of transition management, strategic niche management and sustainability transitions) could be used to enrich the debate on URWH. The water research community in general has been slow to pick up on transitions research (de Haan et al., 2015), in marked contrast to the energy research community. Today, though, there is an emergent debate on urban water transitions explicitly applying transitions research approaches and this is being led by scholars of URWH (Bos and Brown, 2012; Ward et al., 2012; Brown et al., 2013; de Haan et al., 2015).

What intrigues these scholars is how transitions research explains change (and obduracy) to sociotechnical systems in terms of multi-level and multi-phase dynamics (Brown et al., 2013). Transitions are conceived here as a shift from one sociotechnical regime to another (Geels and Schot, 2007). The 'regime' refers to a particular configuration of material and social elements that has, over time, become self-reinforcing and is, consequently, difficult to change. True transitions – i.e. regime shifts – occur in response to pressures from either experimental 'niches' or external forces ('landscape' in the transitions terminology). How these three levels – regime, niche and landscape – interact is elaborated in the so-called Multi-Level Perspective, an explanatory model developed out of numerous case studies and continuously refined (Geels, 2011). The multi-phase dynamics of socio-technical systems is generally explained by way of a common evolutionary pattern, starting with 'predevelopment' and proceeding to 'take-off', 'acceleration' and 'stabilization' phases. This has been applied, for instance, to Brown et al.'s study of Melbourne's shift to sustainable urban water management and found, by and large, to be an accurate representation of the transition process there (2013). In Melbourne, 'pre-development' involved landscape shifts and niche emergence prior to the mid-1990s, 'take-off' the emergence of shared understandings around the new urban water paradigm during the late 1990s, 'acceleration' the dissemination of knowledge and policy around urban rainwater harvesting in the 2000s and '(pre)stabilization' the embedding of stormwater quality practices in a new regime (ibid.) A second study has, with the help of the transitions management literature, identified three phases of experimentation in the urban water sector in Sydney from 2002 to the present, involving first local knowledge acquisition around urban water issues ('deepening'), then replication of the alternative approach to managing rainwater ('broadening') and subsequently alterations to the governance structure ('scaling-up') (Bos and Brown, 2012).

These and other contributions (e.g. Ward et al., 2012; de Haan et al., 2015) are valuable not only for introducing transitions concepts to the water research community and demonstrating how they can be applied, but also – conversely – in bringing a more robust and nuanced understanding of governance, agency and institutions to the transitions debate in general. Nevertheless, from the perspective of our own research objectives this nascent literature on urban water transitions has two major shortcomings: one temporal and one spatial. On the one hand it appears to conceive of transition as a largely linear process, involving a shift from one sociotechnical regime to another in a succession of relatively well defined phases, as illustrated above. This uni-directional pattern of change may well be true for the cases studied, but should not blind us to the possibility or, even, probability that transitions are generally far more messy, characterized by sudden setbacks and periods of stagnation as well as shifts towards more sustainable regimes (cf. Bulkeley et al., 2011a). This relates to fundamental criticisms made of the transitions literature; in particular, that it depicts regimes as monolithic, overemphasizes niches as drivers for change and overlooks political contestation (Smith et al., 2005; Bulkeley et al., 2011b; Fuenfschilling and Truffer, 2014). As Kathryn Furlong has pointed out, conceptualizations of transition as a shift from one sociotechnical regime to another conceal other possible avenues characterized, for instance, by the coexistence of two or more sociotechnical configurations (2014). On the other hand recent research on urban water transitions fails to address explicitly the multiple urban dimensions of URWH. For all the discussion of 'contexts' and their importance in influencing change to cultures, structures and practices (e.g. Bos and Brown, 2012), it is institutional contexts that are invariably meant, not geographical ones. Even those works based on case studies of individual cities (e.g. Melbourne, Sydney) treat the city primarily as a place where innovations happen, rather than an inherent part of the transition process (Bos and Brown, 2012; Brown et al., 2013). Being largely focused on cities and countries of the North, this research – like

transitions studies in general – can also be criticized for making assumptions about transitions that may well not apply to other global contexts (Furlong, 2014). Both these criticisms suggest the emergent debate on urban water transitions could benefit hugely from recent research on the urban dimensions of sociotechnical transitions. It is to this body of work, primarily from human geography and urban studies, that we now turn for further inspiration.

2.2 Understanding the 'urban' in sociotechnical transitions

One of the principal charges levelled against transitions research is that it has in the past been "geographically naïve" (Lawhon and Murphy, 2011: 360). Addressing primarily national innovation processes, studies of sustainability transitions have shown little interest in spatial aspects and conceptualize space in a simplistic manner (Hodson and Marvin, 2010; Coenen and Truffer, 2012). The 'levels' of the Multi-Level Perspective do not refer to geographical scales (Coenen et al., 2012); confusion with the concept of multi-level governance must therefore be avoided. The places where transitions occur are largely absent in transitions studies (Bulkeley et al., 2011a). How socio-spatial relations and dynamics drive transitions is generally overlooked (Coenen et al., 2012). Cities, if addressed at all, are treated either as a space where specific types of innovation occur – as seedbeds of national transitions (e.g. Geels, 2011) – or as a homogenous actor of relative autonomy (Bulkeley et al., 2011b: 33).

Recent work on urban infrastructures in transition, inspired by debates in human geography and urban studies, is mapping out an exciting research agenda in this field. Using relational concepts of the 'urban' and of sociotechnical systems, these scholars are demonstrating on the basis of empirical case studies the multiple ways in which place and scale are important to sociotechnical change in urban contexts. *Firstly*, the constitution of sociotechnical niches and regimes is highly place-specific, requiring a relational understanding of locally-shaped niche-regime configurations (Wolfram and Frantzeskaki, 2016). Place-based approaches in human geography emphasize the importance of proximity, identity and local differentiation to the urban condition (Jessop et al., 2008). Scholars are calling, therefore, for a more sophisticated understanding of how individual cities respond to pressures for change in place-specific ways that reflect these dimensions (Hodson and Marvin, 2009; Coenen et al., 2012; Rutherford and Coutard, 2012). *Secondly*, cities and their infrastructure systems are co-constitutive. That is, sociotechnical systems such as a rainwater network are shaped by urban conditions – physical, political, socio-economic and cultural – whilst themselves exerting influence on urban structures and practices. We need, therefore, to pay greater attention to how efforts to reconfigure a sociotechnical system become entangled in broader urban transitions (Hodson and Marvin, 2010; Bulkeley et al., 2011). Urban development trends, from this perspective, are an intrinsic part of urban water transitions. *Thirdly*, cities can be both places of innovation and local manifestations of sociotechnical regimes (Wolfram and Frantzeskaki, 2016). There are inherent tensions to explore, therefore, between efforts to engender systemic change on the one hand and to sustain incumbent structures on the other. Competing logics for managing water can co-exist in one city (Fuenfschilling and Truffer, 2014). We need to reveal, in the words of Bulkeley et al., "the ways in which obduracy and flux in urban systems is created, maintained and contested" (2011b: 37). It follows from this, *fourthly*, that the relationship between cities and sociotechnical systems is deeply political (Hodson and Marvin, 2010). Transitions are always arenas of contestation between incumbents and challengers. They are themselves not politically benign, but often dominated by urban elites or community groups pursuing particular social interests (Hodson et al., 2011; cf. McFarlane and Rutherford, 2008; Smith and Stirling, 2008). *Fifthly*, greater sensitivity to the fluctual histories of transitions in cities is called for, in order to

confront “the seeming inevitability in some historical accounts of transitions” (Hodson et al., 2011: 199). This means challenging the notion of linear pathways from niche to regime change underpinning much transitions research, in favour of a more nuanced understanding of how temporal contexts and contingent events influence and alter pathways.

These five dimensions of the ‘urban’ – the importance of place, the co-constitution of cities and infrastructures, forces for change and continuity in urban systems, the urban politics of transition and non-linear urban histories – are used to frame the following empirical investigation and will be drawn upon in section 5 to interpret the findings from the case study. The novel contribution to urban geographic theory, it will be argued, lies in bringing these multiple dimensions of the ‘urban’ – developed individually elsewhere – together into one analytical framework and demonstrating its value in studying the interdependence of urban and sociotechnical transitions.

3 Policies, plans and programmes for rainwater harvesting in Berlin

3.1 Research methodology

The analysis of URWH in Berlin in the following two sections looks first at the policy context (section 3) and then at the projects emerging from this (section 4). Both steps are original in that they take a 30-year perspective on the trajectory of URWH in one city, embrace a wide range of instruments and schemes promoting URWH and seek to embed URWH policies and projects within urban development more generally.

The first step involved exploring the policies, plans and programmes which have promoted URWH in Berlin since the 1980s. The literature on URWH in Germany has focused primarily on the technical feasibility and economic efficiency of these alternative rainwater systems. With very few exceptions (Nickel et al., 2014, Schütze, 2013), little scholarly attention has been paid to the policy context of URWH, its relation to water management and urban development and its potential for mainstreaming. In this paper we analyse policies, plans and programmes in order to explicate the urban political and institutional framework within which URWH has been encouraged – or resisted – in different ways at different times. The methodology involved a content analysis of a wide range of documents on policies, plans and programmes pertinent to URWH in Berlin. These comprised primarily laws, municipal statutes, funding programmes, policy guidelines, urban development plans, water management plans, financial incentives and competitions. The scope of these documents was not restricted to explicitly rainwater management instruments, but open to diverse policy sectors in order to reflect the cross-sectoral nature of many URWH schemes. As Nickel et al. have argued (2014) instruments supporting URWH can be found in the fields of nature conservation, landscape and urban planning. Furthermore, we studied not just municipal instruments, but also those at borough, federal and EU scales, so far as they constitute important contextual forces for URWH in Berlin. This is in line with the analysis by Meehan and Moore (2014) of 96 rainwater harvesting policies at different levels across the USA that corroborates the importance of municipal action to support URWH.

Embracing these multiple instruments, sectors and scales, we compiled a database of over 100 policies, plans and programmes of relevance to URWH in Berlin, dating from the late 1980s to 2015. Although impressive in size, this database of diverse instruments poses methodological challenges for the analysis. Firstly, the information available on each instrument differs greatly depending on the type of

instrument and its timing. The more paradigmatic and more recent they are, the better they tend to be documented online. Secondly, the degree to which each has influenced the trajectory of URWH in Berlin could not be considered. Our interest lay, rather, in studying those instruments which possess the potential to influence URWH, intentionally or unintentionally. Thirdly, our initial quantitative analysis of these instruments (section 3.2) can only be indicative of phenomena worth studying further, which is why we complement it with a more in-depth qualitative content analysis (section 3.3), which additionally draws on semi-structured interviews with key actors of water management, environmental protection and urban development in the city. Of the 26 interviews conducted during the course of our research, only the 17 pertinent to the city-wide scale were included in the analysis for this paper (see list following references).

3.2 Indicative quantitative analysis

We first analysed the instruments collected in the database quantitatively, according to three sets of categories. These relate to a) the mode of support for URWH (i.e. whether the instrument requires, promotes or informs), b) the policy sector the instrument addresses (i.e. urban planning and development, environmental protection, water management or 'other') and c) the timing of the instrument (i.e. when it was introduced, clustered into 5-year periods).

For the first category we adopted a simple three-fold classification for modes of support as proposed and applied by Ansel (2011: 21). 'Require' includes general and administratively binding instruments. 'Promote' comprises tools incentivizing certain behaviour and practices, generally through direct and indirect subsidies and funding, as well as direct implementation by public authorities. 'Inform' entails tools providing information and reporting on best practices, innovative technologies etc. to raise awareness and increase knowledge. By way of illustration, Table 1 provides some examples of specific instruments for each of these categories.

Require	Promote	Inform
Laws	International Architecture Exhibition	Brochures
Tender requirements	Urban development funding programmes	Reports
Technical standards	Wastewater tariff systems	Maps
Binding planning instruments	Competitions	Strategy documents
	Pilot projects	Roadmaps
	Public landscape interventions	

Table 1 Categories and illustrative instruments. Source: own compilation.

Figure 1 depicts the distribution of the instruments from the 1980s to 2014. Overall, the number of instruments is high but varied across this period, with a peak in the years 2005-2009, but also following reunification of the city between 1990 and 1994. The graph on the left presents this temporal distribution in terms of the three modes of support for URWH. This reveals a general predominance of 'require' instruments, but growing significance of 'promote' instruments around the turn of the century and of the 'inform' instruments recently. The graph on the right presents the temporal distribution according to the policy field of each instrument. Here, it is striking that instruments of urban planning and development were predominant until the mid-1990s, after which water

management instruments became the most significant statistically, with a growing number of instruments attributed to environmental protection.

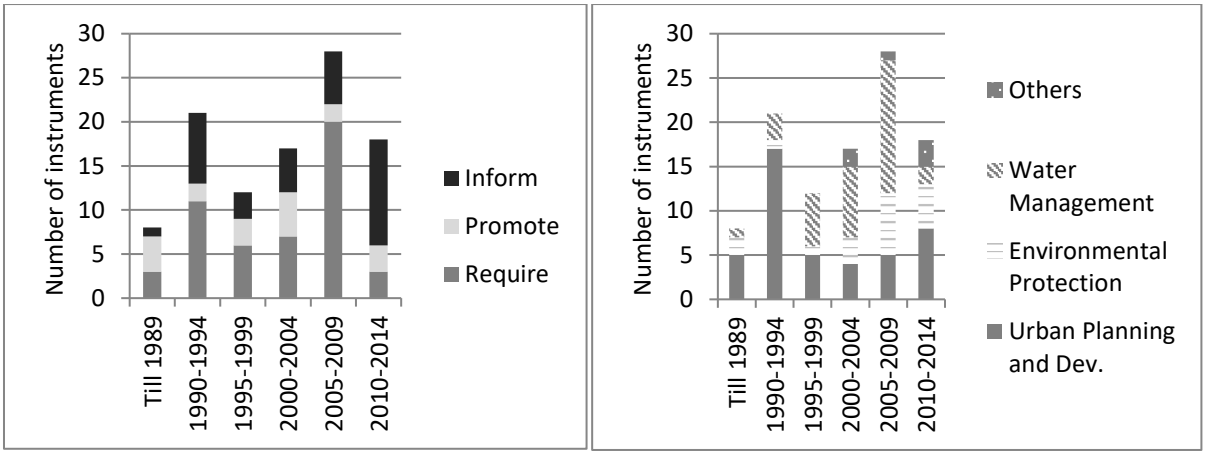

Figure 1 Temporal distribution of instruments based on their type (left) and policy field (right). Source: Own compilation.

This simple quantitative analysis suggests, with due consideration of its methodological limitations, several significant trends to URWH in Berlin. Firstly, there has been continuous – though by no means constant – development of instruments promoting URWH in one form or another across a 30-year period. Secondly, not all instruments promoting URWH have originated within the field of water management, as might be expected. Urban planning and development has been just as significant a driver, especially in the period immediately before and after reunification in 1990. Thirdly, the prominence of regulatory ('require') and funding instruments ('promote') indicates a strong role of the state, primarily the city government. This emphasis, interestingly, appears to have changed over time: from the use of public subsidies for urban development projects in the early years via a stronger regulatory presence around water management and environmental protection in the 2000s to a more hands-off, informative role encouraging private initiatives for URWH from 2005 onwards. We may detect from the analysis, in other words, a gradual but clear shift from command-and-control instruments towards more indirect and passive support of RWH systems, according a greater role to private actors. How far these shifts reflect changes in urban development and politics over time is addressed in the following qualitative analysis.

3.3 Explanatory qualitative assessment

The findings of this initial, quantitative analysis encouraged us to conduct a more contextualized, qualitative assessment of the data in order to discover how far the emergence of certain types of instruments at certain times be explained – in part, at least – by shifts in urban development priorities and the political economy in Berlin. Figure 2 depicts a timeline of relevant developments and events in Berlin from 1981 to 2016. These are divided into two categories: water politics and urban politics. A further distinction is made between contextual trends (horizontal bars) and contingent events (vertical lines). This diagram is used here to provide orientation in identifying the shifts in policy support for URWH in Berlin, but also to offer explanations for these shifts in terms of urban change. In doing so, we acknowledge that the 'urban' is not the only spatial context for URWH in the city and include therefore also select 'external' forces (e.g. the EU Water Framework Directive, global climate change) that have shaped the debate on rainwater management significantly.

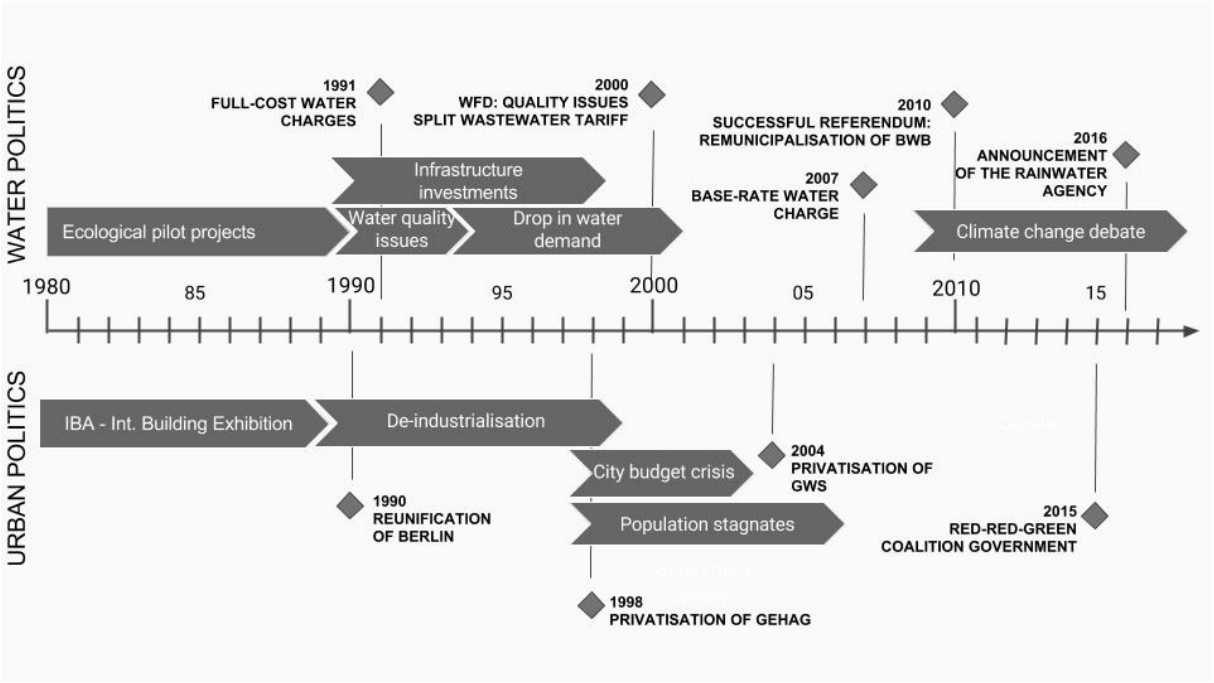

Figure 2 Timeline of key trends and events in Berlin pertinent to URWH. Source: Own compilation.

The first URWH projects in Berlin were, as the quantitative analysis suggested, powerfully promoted by regulatory and funding instruments in the field of urban development. The high priority accorded to housing development and urban renewal in West Berlin during the 1980s created a niche for ecological innovation within which emergent technologies of rainwater harvesting could be tested on urban experimental sites. At this time the long-standing housing policy of site clearance and rebuild (so-called *Kahlschlagsanierung*) was coming under severe criticism from residents, provoking social protests and an active squatters' movement (cf. arranca.org, 2011). This generated interest in alternative housing concepts oriented around using and refurbishing existing buildings, termed "careful urban renewal". An International Building Exhibition (IBA) ran from 1979 to 1987 to showcase West Berlin as a forward-looking, innovative city in terms of green architecture and urban planning. The IBA offered a platform and an enabling framework to test various alternative green solutions, including URWH, in newly constructed as well as refurbished buildings. These experimental sites – such as Block 6 in the borough of Kreuzberg – set the stage for subsequent pilot projects and were a source of learning for those involved, many of whom are still working as consultants.

Following reunification in 1990 the city authorities, concerned about an impending water supply crisis, drew on this experience to promote ecological measures in housing (re-)developments across the city, applying a combination of regulatory requirements and financial incentives. Municipal statutes specified ecological requirements for newly-built and refurbished social housing (1990-2002) and for public and publicly financed buildings (from 1994 onwards). To promote take-up, the city offered grants or low/no interest loans to developers prepared to include green technologies in social housing developments. The objective here was to demonstrate that ecological improvements – including alternative ways of managing rainwater – could be achieved in socially deprived communities. A major urban renewal funding programme, established originally in 1983 but extended until 1995, supported greening measures on an unprecedented scale. It funded greening measures in 1.643 projects, resulting in 740.000m^2 unsealed yards and 65.000m^2 greened roofs throughout the city (cf. Reichmann, 2009). A similar programme of this scope has not been implemented since. In addition, various pilot

projects on ecological construction were carried out between 1988 and 2001 within the programme Urban Ecological Model Projects, designed to test, encourage and enable the standardization of innovative solutions. Although not designed to promote URWH explicitly, all these instruments provided a crucial stimulus for owners, architects and developers to consider alternative forms of rainwater management, illustrating how URWH emerged as a largely unintended, positive side-effect of public policies targeting much broader issues of urban development.

The mid-1990s saw a significant shift in Berlin's policy towards URWH (Moss, 2000). Massive economic restructuring post-reunification and several ill-founded city investments engendered a serious budget crisis. The city government felt obliged to drop its generous funding programmes, privatize parts of its housing stock (e.g. GEHAG and GSW) and utilities (including the municipal water company BWB) and seek other means of pursuing its ecological objectives. At the same time, priorities of water management were changing radically. Rapid de-industrialization, water-saving appliances and full-cost water tariffs had combined to reduce water consumption in the city by almost 40% in 1995 (Moss, 2008). The EU Water Framework Directive (WFD) of 2000 targeted problems of water quality, rather than quantity. All these factors prompted a shift – visible in the quantitative analysis above – from instruments that 'promote' to ones that 'require' or 'inform', as well as from instruments in the field of urban development and planning to ones in the fields of water management and environmental protection. The direct impact of this new generation of instruments on URWH is hard to assess, although we can detect a decline in the number of new URWH projects in the decade 1995-2005 (see following section). Significantly, the principal instrument designed to address water quality issues in Berlin was an infrastructure investment programme, launched in 1998, to increase the storage capacity of the combined sewer system by constructing or expanding underground retention basins and installing automatic devices to reduce sewer overflows (cf. Senatsverwaltung für Stadtentwicklung und Umwelt, n.d.; Sieker, 2013).

Notwithstanding this reinvigorated trust in large-scale, hard-engineering solutions, a split wastewater tariff was introduced in Berlin in 2000 as a means of promoting URWH across the city. The split tariff consists of a fee per m^2 of sealed area for each property, with the option of paying no fees or getting discounts for surfaces with no or low run-off. Thus, for instance, grass pavers or special permeable laying systems are not charged at all, green roofs are charged for 50% of the actual surface and trough-trench systems are charged for 50% of the total surface. This financial incentive for all property owners to retain rainwater on site marks a departure from the earlier funding programmes that subsidized URWH techniques and, equally, a broader shift in urban policy instruments from direct funding to indirect incentives as a response to the city's budget crisis. In assessing its impact, Schütze (2013) concludes that savings in wastewater fees are significant for those who own large properties or use significant amounts of (rain)water, a finding corroborated by several of our interviewees (Interviews 1, 2 and 3).

The effectiveness of this novel incentive is, of course, dependent on the level of wastewater and water tariffs. Following the partial privatization of the Berlin Water Company in 1999, these tariffs were increased so sharply that, after protests from consumers, the Cartel Office intervened in 2012 to force the company to reduce drinking water fees (cte/dpa, 2012). The wastewater fee has also been reduced, to 2.303 €/m^3 in 2016. The rainwater fee increased until 2010 and has remained relatively stable since, standing at 1,804 €/m^2 in 2016 (Berliner Wasserbetriebe, 2016). However, it is generally considered too low to provide a significant incentive for the introduction of URWH techniques. Strehl et al (2016) have calculated that the costs for implementing URWH in Berlin are borne

disproportionally by private owners, with poor prospects for short-time amortization. The split wastewater tariff in Berlin – widely regarded as an innovative instrument for URWH – has, nevertheless, been flanked by regulatory incentives, notably the Exemption of Rainwater Decree (NwFreiV), which sets out how rainwater be be infiltrated on site without formal permission if outside a drinking water protection area.

Instruments of spatial planning, interestingly, are not used to significant effect to advance URWH in Berlin. According to our interviewees (Interview 4), the option of securing zones for rainwater management in urban plans at borough level is hardly used. An exception is a planning procedure whereby the city and the Berlin Water Company can require property owners and developers requesting permits for construction or renewal projects to unseal surfaces or reduce discharges into the sewer system in areas where the mainline infrastructure or local environmental is particularly vulnerable. This is another interesting example of how the water utility is entertaining rainwater retention in so far as it complements and protects its existing sewage disposal network.

In the last 10 years a renewed interest in URWH can be observed, accompanied by a fresh generation of instruments. Several environmental protection schemes have provided substantial funding (once again) for URWH projects in Berlin, notably the Environmental Relief Programmes I (2000-2006) and II (2008-2015) financed primarily with EFRE funds. In addition, a plethora of strategies and plans ranging from the EU to borough levels have been designed to raise public awareness and set new ambitions for an environmentally sustainable city. Interestingly, these instruments are addressing broader concerns, such as climate change, biodiversity and quality of life in the city, and targeting information, rather than funding or regulation, as the principal means to enact change. A good example of this is the Urban Development Plan – Climate (StEP-Klima), a strategic framing document approved in 2010 and updated in 2016 that promotes greening, unsealing and rainwater use as effective measures for adapting to climate change.

To sum up, we can observe significant shifts in the instruments applied to promote URWH in Berlin which reflect, largely, changes in the city's political economy and urban policy priorities. What began as a product of urban housing and development policies around the 1990s has become an issue addressed increasingly by policies, programmes and plans targeting improvements to environmental protection, climate change and water management in the city. URWH, in other words, is promoted by a range of urban policy fields, often as a complementary side-effect. Equally, we detected major shifts in the types of instruments predominant at particular times. The strongly pro-active role of the local city-state of the early years, executing its own pilot projects and providing substantial public funding, gave way to a low-cost, passive approach in response to the city's budget crisis and privatization wave of the mid-1990s, relying more heavily on 'require' and 'inform' instruments to encourage private initiatives of URWH, thereby transferring responsibility for implementation to the city's residents and businesses. A final point we noted was the coexistence of instruments promoting URWH and ones sustaining conventional rainwater disposal via sewers. This suggests an ambivalent attitude towards URWH in policy-making circles, sending mixed messages to residents and utility alike. It strengthens the argument that both city authorities and water utility perceive URWH primarily as a complement to the existing sociotechnical regime in places where it needs relief.

This attitude – and the policies it generates – may, however, be changing in the future. A new coalition government of the Social Democratic, Left and Green parties was formed in December 2016 with the ambition to prioritize URWH as a core component of the city's response to climate change. This

government has announced plans for a new rainwater agency that will be entrusted with overseeing over 1,000 roof greening projects, designed to reduce rainwater discharge to the combined sewer system by 1% annually. According to the head of the Berlin Water Company, Jörg Simon, this policy represents “the first systematic approach ever taken on rainwater management in Berlin” (statement at public event on 13.12.2016).

4 Berlin’s rainwater project landscape

What kinds of URWH projects have been generated by these instruments and their urban contexts over the past 30 years? The following section maps Berlin’s rainwater projects and analyses them in terms of their location, timing, design and use.

4.1 Research methodology

The source of our analysis is a database of over 250 URWH projects launched in Berlin over the past 30 years. This database was compiled by the authors by means of an online-based research of all URWH projects that have been implemented – i.e. not just planned – between the mid-1980s and 2014. It is consequently biased in favour of projects with their own website, media coverage or references in the websites of others. These tend to be either larger projects driven by public or commercial actors or ones receiving public funding. For this reason the database does not, for instance, include the 1,643 small projects supported by the programme funding greening measures between 1983 and 1995 because not all are documented online. In other words, the prevalence of URWH is even larger than the ca. 250 cases included in the database. Despite being incomplete, the database is a unique and valuable collection of data that illustrates the considerable extent, diverse types and evolutionary trends of URWH projects executed in the city.

Using the database, the projects were clustered according to their size, timing, location, type of site or building and use. Of particular interest for this paper is the temporal evolution of the projects as well as their spatial distribution across the reunited city of Berlin. It should be noted that pre-1990 data refers to West Berlin only. To graphically depict this information, graphs and a map were developed. Based on the parameters included in the database, the projects were grouped into project types deemed illustrative of URWH in Berlin.

4.2 Mapping URWH projects in Berlin, 1985-2014

The spatial distribution of the ca. 250 documented URWH projects in Berlin is presented in Figure 3. The percentages given relate to all projects, excluding those where no location was given or which cover more than one city borough. A distinction is made, for the purpose of this paper, between ‘blue’ and ‘green’ rainwater projects. ‘Blue’ refers to projects with physical infrastructures for rainwater retention, infiltration and/or use, including greening. ‘Green’ refers to projects solely with greening (e.g. unsealed surfaces, green roofs), i.e. without a rainwater infrastructure component. Blue projects comprise 43% of the total, while green projects comprise 57%.

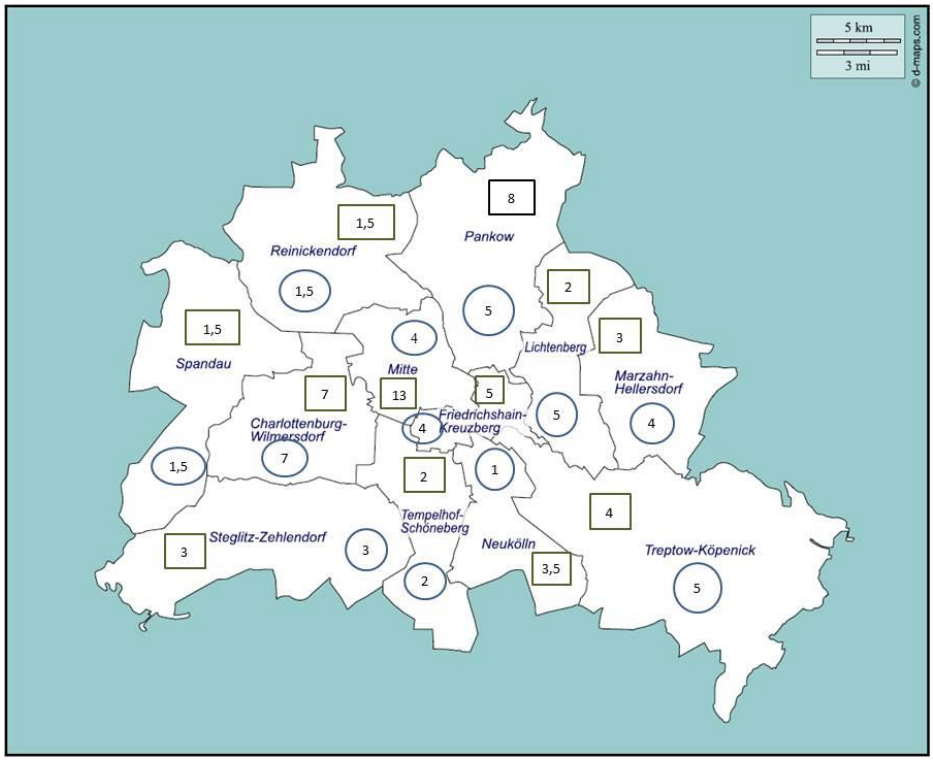

Figure 3 Map of Berlin indicating distribution of URWH projects, by borough, in per cent of total.

Key: 'Blue' projects indicated in circles, 'green' projects in squares.

Source: own compilation

This map illustrates, in the first instance, that URWH projects can be found all over the city. A closer look reveals some important differences in spatial distribution. There are, in general, a larger number of URWH projects in the inner-city boroughs (Mitte, Charlottenburg-Wilmersdorf, Friedrichshain-Kreuzberg) than in the suburbs. It is in these boroughs, too, that most of the 'green' infrastructure projects are located. This can be explained in part by the priority given there to greening dense urban structures, for aesthetic and urban heat reasons, but also by the relative ease of incorporating greening elements in built-up areas. Up until the early 2000s many of the 'green' projects in these inner-city boroughs were large scale and state-driven, reflecting policy priorities for urban renewal and redevelopment especially in the Eastern part of the city. Subsequent 'green' projects in inner-city areas have been smaller in scale and more frequently run by private residents, owners or businesses. The predominance of 'blue' projects in the outer-lying boroughs can be explained by the greater availability of land, the location of new urban developments there, the place-specific rainwater challenges and the prevalence of a separate rainwater sewer making local rainwater retention easier. For the 'blue' projects it is difficult to draw definite conclusions on the predominance of certain project types in terms of their purpose and location. However, a certain relation can be observed between their size and location, with larger projects generally being located in areas further away from the city centre. The spatial distribution of 'blue' and 'green' URWH projects is only one way of pinpointing place-specific features within the city. In the following section we take a closer look at other key characteristics and offer explanations for their place specificity.

4.3 Analysing the projects

The following graphs illustrate the chief characteristics of these 250+ projects. To this end we clustered the projects according to their infrastructure type ('blue' or 'green'), but also to their timing (in 5-year periods of the commencement date), size (large: over 5.000m^2, small: up to 5.000m^2) and site use (residential, commercial or public).

Figure 4 presents the temporal distribution of the registered projects based on the site or building where they are implemented. The graph shows a relative predominance of projects in public spaces and buildings for both 'green' and 'blue' types, representing 52% of all projects. There is, however, a strong growth in 'green residential' projects from the 2000s onwards. In the case of 'blue' projects public ones are predominant throughout, but commercial projects have increased in the last ten years. This finding needs to be considered against the methodological shortcomings likely to leave small, privately-funded projects underrepresented. Nevertheless, the significant statistical shifts represented here do mirror the emergence of different instruments during the 2000s (see previous section) that favoured private and commercial over public projects, indicating to a clear shift in urban development paradigm from an interventionist to an incentivizing state.

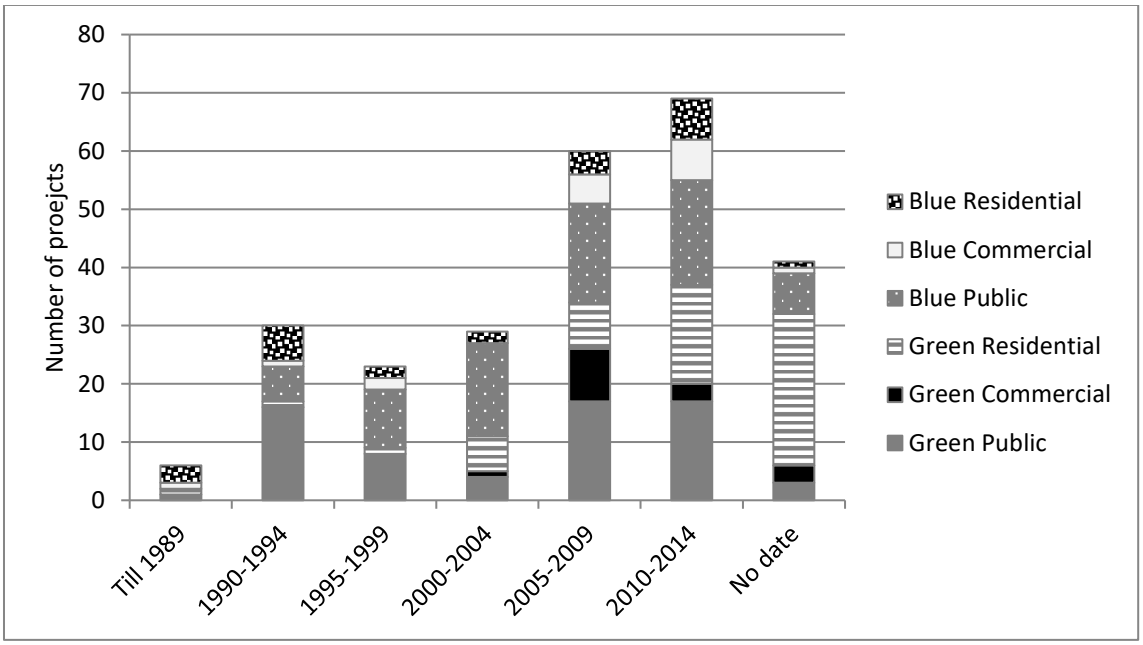

Figure 4 Temporal distribution of projects implemented according to the type of site / building. Source: own elaboration

Figure 5 illustrates the distribution between public, commercial and residential URWH projects in terms of their type and size. It shows the importance of the city government in providing sites and buildings for large-sale projects of both 'green' and 'blue' types across the observed time span. Most of these were carried out in officially declared urban development and renewal areas by public authorities and in public parks. The larger residential projects emerged later and were supported largely by the programme Urban Ecological Model Projects, mentioned in the previous section, aiming at demonstrating showcase schemes and setting the city up as a front-runner in ecological construction and urban planning. These residential projects reflect the importance to urban policy of housing construction, life quality and investments in infrastructure following reunification in 1990. There was an increase in small projects on residential and commercial sites in the mid-2000s, mostly in the form of greened roofs and yards. However, many 'blue' projects on commercial sites are very often large

and involve various rainwater technologies. They emerged largely in response to requirements by the authorities or the water utility to limit discharges issued in the context of urban development or renewal projects. Economic motives played a key role in encouraging the take-up of URWH technologies by Berlin's business community.

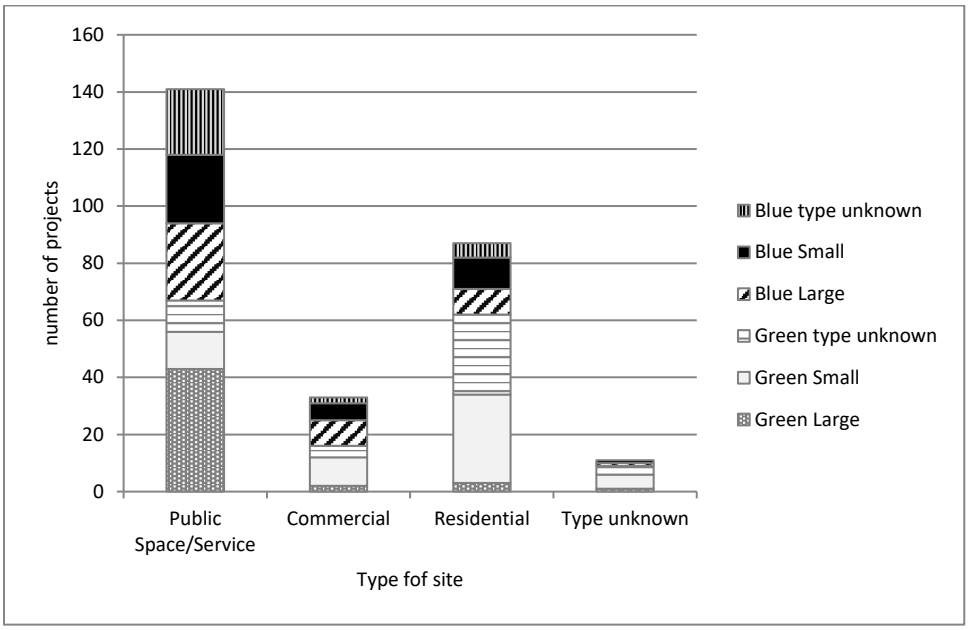

Figure 5 Distribution of projects according to type of site and size. Source: Own elaboration

Finally, our database reveals a cluster of small residential projects where rainwater harvesting systems have been installed. This group is likely to be underrepresented in our analysis because private households usually do not make information of this kind available online. They, are, however highly significant, relying heavily on the initiative of the actors involved (architects, residents, owners). In the context of Berlin's housing culture they represent in many ways the diverse, alternative modes of living that the city at first tolerated and subsequently nurtured. Many of these small residential projects have their roots in the green housing initiatives of the late 1970s and early 1980s and are located in centrally-located tenement blocks dating from the late nineteenth and early twentieth century.

5 Rain and the city: Interpreting the findings

In this section we revisit the five analytical dimensions of the 'urban' developed in section 2 and apply them to interpret the empirical findings in sections 3 and 4 in terms familiar to debates on urban water and urban infrastructure transitions.

Place

The significant of place has been highly apparent throughout the analysis. The instruments promoting URWH (deliberately or inadvertently) in Berlin are all, as we have demonstrated, products of a particular urban context at a particular time. The choice of public subsidies in the 1980s to mid-1990s was an expression of an interventionist urban policy at that time, made possible by the availability of considerable public funds. Likewise, the departure from this approach and the emergent preference for more regulatory and informative instruments was a direct response to the city's budget crisis and

the appeal of neo-liberal modes of delegating responsibility to user communities. The huge variety of URWH projects in Berlin also reflects significant shifts in urban policy priorities, from urban renewal and ecological modernization to climate change and stormwater retention. Each of these policies generated particular kinds of URWH projects – ranging from small-scale, experimental residential schemes to larger-scale trough-and-trench systems in public parks – that reflect very place-specific topographies and identities within the city.

Co-constitution of cities and infrastructures

The relationship between the city and its infrastructure is, however, not a one-way street. For all the multiple ways in which the physical geography, political economy and social culture of Berlin has enabled or resisted the dissemination of URWH, the city's stormwater infrastructures – understood here as sociotechnical systems – have themselves influenced urban politics and development. This became apparent, for instance, over the collapse of water consumption in the early 1990s and the resulting problems of infrastructural over-capacity, which prompted the city authorities to reframe URWH as a solution not to water quantity but water quality problems. It is also clearly visible in the way that the two wastewater systems in the city – a combined sewer system in the city centre and a separated wastewater/rainwater system in the outskirts – have created very different opportunities for URWH. Intriguingly, however, the city's water utility BWB has not played an active role in most URWH projects. This is due largely to the BWB not being responsible for rainwater on individual properties but only when it reaches public areas, such as streets.

Forces for change and continuity in urban systems

What our analysis has revealed is that efforts to promote URWH have always been confronted with forces for both change and continuity. Even at times when the factors favouring URWH were in the ascendance – for instance, in the late 1980s and early 1990s, buoyed by considerable public funds – there were still significant obstacles to dissemination, not least in the reluctance of the city's water utility to depart from its traditional reliance on a proven network of underground sewers and sewage treatment works. Such forces for continuity can, however, be destabilized by contingent events or trends. The EU Water Framework Directive can be seen as one such stimulant to rethink rainwater management as a quality, rather than quantity, problem and thereby reframe the motives for, and design of, URWH. Today, the Berlin Water Company sees URWH not as a challenge, but rather as a complement to its existing rainwater management system, helping to keep it operable under changing climatic and demographic conditions. Forces for change and continuity, in other words, not only coexist in any one city; they can be fruitfully combined.

Urban politics of transition

None of these forces, shifts and trends for or against URWH are politically benign. They are all products and means of political expression. This is perhaps most starkly revealed in the changing role and priorities of the city government across this 30-year period. The early financial support given to URWH in the context of urban renewal projects reflected a mode of state interventionism characteristic of West Berlin which resonated into the post-reunification era. This produced a particular kind of URWH project: mainly in large-scale public or residential developments and highly dependent on public subsidies. Subsequent retrenchment in the wake of economic restructuring and the budget crisis of the reunified city prompted a departure from this model of political support, engendering less costly ways of encouraging others to take the initiative, relying on instruments that 'require' or 'inform'

rather than 'promote'. This finding resonates with earlier research on shifts to infrastructure governance in the city during the 1990s (Beveridge, 2012; Monstadt, 2007). Today, we may be witnessing the beginning of a new area of state involvement, as indicated by the high priority according to rainwater management in the coalition contract of 2016 and the pressing need for new housing to meet rising demand from a now growing population. The contested nature of urban water politics was most apparent in the controversy over the partial privatization of the Berlin Water Company in 1999 and the (ultimately successful) campaign to re-municipalize the company in 2011 (Beveridge, 2012). Although not explicitly about URWH, the ownership issue did affect the way it was supported, in particular in the way the split wastewater tariff became embroiled in the politics of rising water tariffs.

Non-linear urban histories

A final finding is that the development trajectory of URWH in Berlin has been anything but linear. The development phases popularly used in the literature on sociotechnical transitions – beginning, for instance, with predevelopment and proceeding to take-off, acceleration and stabilization phases – are not very helpful in characterizing the career of URWH in Berlin, suggestive as they are of a continuous process of advancement. As we have noted in both empirical sections, there have been dips in the dissemination of URWH in the city, notably in the late 1990s, and it would be misleading to construct over the 30-year period a linear trajectory of political design, in which each instrument builds meaningfully and seamlessly onto an existing package of incentives. As Kathryn Furlong (2014) and other scholars have recently been arguing, thinking of transitions merely as a switch from one sociotechnical regime to another misses important issues of coexistence, non-linearity and incompleteness. These features, our study has shown, are not limited to the global South, but can also be found in highly developed urban contexts. We need, therefore, to be mindful in future of the inherent messiness of sociotechnical trajectories in cities.

6 Conclusions

Recent social science studies have provided important pointers to institutional factors impeding the mainstreaming of rainwater harvesting technologies in cities and are increasingly using sociotechnical concepts to explain urban water transitions. What is largely missing in these accounts is a sense of how particular spatial and temporal contexts shape trajectories of URWH. The thrust of this paper, consequently, has been to unpack the 'urban' in URWH and to explore the dynamic interdependencies of rainwater infrastructures and urban development, using the case of Berlin as an exemplar. It has drawn on two bodies of scholarship – on urban water management in transition and on urban dimensions of sociotechnical transitions – to inform a study of the shifting policy context and project landscape of URWH in Berlin from the mid-1980s to the present day.

Returning to the four research questions posed in section 1, we here elucidate the key findings emerging from our analysis and their implications for future policy and research. The first question asked to what ends and by what means URWH has been promoted in Berlin. Our study of the instruments applied since the 1980s revealed a panorama of huge variety. The policy sectors enrolled in driving URWH varied significantly, from housing development to water protection and climate change. So did the types of instruments used, ranging from public subsidies and cost-saving incentives to regulations and awareness-raising campaigns. Significantly, this variety was unevenly spread across the 30 years under study, with some periods characterized by high levels of public funding around

housing (re-)development programmes and others by greater reliance on regulatory instruments addressing, in particular, water quality. These significant shifts in thematic emphasis and governance approach can be directly attributed to changing political priorities in the city government. URWH has, at different times, been enrolled to serve social policies of ecological housing, water protection policies to minimize runoff and climate protection policies to reduce urban heat. From this, we argue that attempts to promote URWH should not be limited to water-specific instruments alone, but embrace the gamut of policy fields and instruments that can be conducive to retaining and using rainwater locally. Research on URWH in future should also pay greater attention to the (often hidden) variety of drivers at play in any one city. The case of Berlin also demonstrates that working with multiple incentives requires systematic coordination and planning. This has been noticeably lacking in Berlin, resulting in a low level of knowledge exchange. A recently announced ecological urban plan, however, may provide the kind of policy framework needed to generate a more coordinated, city-wide initiative for URWH (Senatsverwaltung für Stadtentwicklung und Wohnen, 2017).

In response to the second question, about what kinds of URWH projects have emerged, we identified and categorized a similarly impressive variety of schemes. These ranged from experimental sites for alternative technologies run by individuals exploring new ways of communal living, via large-scale urban development projects incorporating extensive trough-trench systems to commercial schemes designed to save costs on wastewater and rainwater disposal. URWH projects could be found across the whole city, but with a higher proportion – particularly of 'green' infrastructure schemes – in the inner-city areas. The technology-intensive 'blue' projects were primarily to be found in the suburbs, where space is less scarce. The timing of URWH projects also revealed intriguing differences. In tune with shifts in the instruments applied, we detected a predominance of large-scale schemes in public housing and parks in the early years, followed by smaller, privately-owned projects on residential, but also commercial properties, since the 2000s. The multiplicity and dynamics of URWH projects in one single city call on policy makers, when considering what projects to promote, to be open to diversity and explore what incentives can suit what type of project best. Scholars, too, are encouraged to seek out diverse projects in their studies of URWH, analysing their relative strengths, requirements and place-making qualities.

Thirdly, our case study highlighted critical interactions between urban development and rainwater management through the lens of URWH policies and projects. We used a timeline of development trends and contingent events in Berlin since the mid-1980s to help contextualize the above shifts in policy and project development. Without claiming direct causality, we ascertained plausible correlations between changes in Berlin's political economy and the role of the (local) state on the one hand and changes in the kinds of programmes, plans and projects promoting URWH on the other. The marked break in public funding for such schemes around the mid-1990s, for instance, can be attributed largely to the city's budget crisis and an emergent neo-liberal approach to urban development and environmental protection. Paying attention to shifting urban contexts not simply as a stage, but primarily as a medium, for advancing URWH would appear to be crucial in designing appropriate policies. In future work this relational analysis could reach beyond the realm of formal policy mechanisms, studied here, to encompass also informal institutions and practices surrounding URWH.

This brings us to our fourth and final question: how our findings can advance knowledge on the role of the 'urban' in sociotechnical transitions. From our literature review we identified five dimensions of the 'urban' of relevance to the interface between urban transitions and sociotechnical transitions: the importance of place, the co-constitution of cities and infrastructures, forces for change and continuity

in urban systems, the urban politics of transition and non-linear urban histories. These we applied as analytical categories to interpret the empirical findings. Thus we were able to demonstrate how the evolution of URWH policies and projects in Berlin has been shaped by very place-specific factors, such as the reunification of the city, the subsequent collapse in water consumption and the budget crisis. We found evidence not only of how urban development frames options for rainwater systems but also, conversely, of how water infrastructures – understood as sociotechnical systems – can influence political debates in the city. We noted the coexistence of forces for transition (around URWH technologies) and obduracy (around the existing sewer network), illustrated nicely by the willingness of the Berlin Water Company to accommodate URWH where it can prevent sewer overflow problems. We highlighted the deeply political nature of these relations, as exemplified by the shifting role of the city government during the 30-year period and by the contestation over water tariffs and the partial privatization of the water utility. We, finally, used the Berlin experience to challenge conventional models of linear transition pathways and sensitize scholars to the messiness of urban water management trajectories, which can involve reversals, diversions and sudden leaps. In sum, all five analytical categories generated important insight into what the 'urban' can mean and why it can be significant to the advancement of UWRH. Applying them in this combination in future research of urban water transitions – and urban transitions more widely – would be, we argue, a most fruitful endeavour. Conceptually, the analytical categories developed in this paper can provide transitions scholars with a set of tools to unpack diverse dimensions of the 'urban' in transitions, whilst demonstrating to human geographers how familiar spatial concepts can be enriched with (less familiar) temporal dimensions that are at the heart of any transition process.

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